3. Cases in Japan

3.1 Use of hot springs

(1) History of hot springs

With rich geothermal resources, Japan has long utilized hot springs not only for bathing but also for drinking, recuperation, recreation, and sightseeing. Dogo Onsen, Ehime prefecture; Arima Onsen, Hyogo prefecture; and Shirahama onsen, Wakayama prefecture are recognized as the three oldest Japanese hot springs. Iyo-no-yu (currently Dogo onsen) is said to be the oldest referenced hot spring in literature, written about in "Kojiki," "Records of Ancient Matters." This text is the oldest existing chronicle in Japan, dating from the early 8th century (711–712). The Iyo-no-yu area was also the only hot spring county, "Yunokori," in Japan that was named after a hot spring. It was established through the local governmental system known as Kokugunrisei designated by the Taiho Code, the first Japanese administrative code established in 701.

The Iyokoku Fudoki (geographical record compiled by imperial order in 713 CE) mentions in a myth that *Okuni nushi no mikoto* made the hot spring, "Hayami-no-yu" in Oita prefecture. It gushed from the foot of Mt. Tsurumi in Oita, ran through the "shitabi" (culvert) into the Hoyo Channel to Dogo Onsen, and healed Sukunahikonomikoto from illness.

The word ONSEN first appeared in Fudoki. It describes the usage, efficacy, and features of hot springs in various locations. The scenery of the then hot spring areas can be vividly imagined. Some older records written in the Kamakura period (1185～1333) mention that provincial governors and influential temples took control of the hot springs. Samurai and high priests used hot springs as resorts for medical treatment and recreation. In the Edo period (1603～1868), besides the Shogun and Daimyo (feudal lords), farmers and townspeople could use hot springs with permission. Eventually, guidebooks and onsen rankings were published. Hot springs began to be widely used by various citizens throughout the nation.

In the modern age, with the development of drilling technology, the style of hot springs has shifted from the outdoor bath to the indoor bath as used in inns. As a result, hot springs began to have a variety of functions as not only health spas for medical treatment but also as places for recreation and sightseeing.

In the Showa period (1926-1989), the railroad network greatly advanced thus allowing many people to easily visit hot spring resorts. In addition to the remarkable development of hot spring resorts, research began to proceed in various fields such as hot spring geology, medicine, engineering, and planning, along with the establishment of the Geophysical Institute of Kyoto University, now known as Kyoto University Graduate School of Science and the Science Department of Geothermal Research Facility. Also, the Kyushu University Spring Therapeutics Research Institute (currently Kyushu University Hospital Beppu) began in this period.

(2) History and features of hot springs in Oita Prefecture

Hot springs in Oita Prefecture have an ancient history. The Bungo Fudoki (geographical record compiled by imperial order in 713 CE) describes Beppu Onsen, Nagayu Onsen, Amagase Onsen, and Iyokoku Fudoki. It also notes the well-known Beppu onsen "Hamawaki-no-yu" and "Bungo Beppu-no-yu" (both in Beppu). These two are both listed in the hot spring rankings of the period, which suggests that Beppu was already a very popular hot spring resort at the time of publication.

Depending on the quality of the water content, hot springs are classified into 10 types. The Beppu onsen are called "Beppu Hatto" or the Eight Hot Springs of Beppu. These springs contain eight different types of water quality. They do exclude two types: the "spring containing iodine" and the "radioactive spring."

In addition to boasting a varied number of spring sources and record amounts of gushing spring water, the Beppu onsen are attractive for other remarkable reasons. Beppu residents can draw hot spring waters into their homes; neighbors share communal bathhouses; and people living in the same apartment building can use a communal bathroom, thus making hot spring culture a vital part of life in the community.

【References】

Ishikawa Michio (2018): History of hot springs, hot springs in the Kojiki and the Nihon Shoki, warrior's secret hot spring, hot springs ranking, Chuko, p. 248

Daigin Economic Management Institute (2017): Oita hot spring white paper, p. 168

3.2 Examples of hot water utilization

3.2.1 Examples of greenhouse cultivation use

The most representative of the plants cultivated using steam and hot water in greenhouses throughout Japan are vegetables. These include tomatoes, cucumbers, mitsuba, paprika, fruits such as strawberries, tropical fruit, mangoes, fungal bed shiitake mushrooms, and flowers including the butter orchid and cyclamen.

The Mori geothermal power plant in Mori-machi, Hokkaido that started in 1982, is a typical example of hot spring use for vegetable cultivation. It has a rated output of 25,000 kW. At this power plant, after separating and extracting steam for power generation, a portion of the hot water, at 120°C, is returned to an underground reinjection well. That well leads to a heat exchanger and is then mixed with river water. That hot water, at around 65°C, is obtained by a heat exchanger and is then distributed to a neighboring greenhouse complex. Within the greenhouses, hot water piping is installed on the ground and heats the room to over 25℃, even when the outside air temperature is -15°C. Tomatoes and cucumbers are grown, throughout the year, and they are shipped to the Kanto region, earning revenue.

The mango of Teshikaga, Hokkaido is a typical example of fruit cultivation. Hot water is drawn from the source at 80°C and at 160L/min and is used to maintain greenhouse internal temperature from 23°C to 25°C throughout the year. The ripened mango has been developed into a brand known as "The Sunset of Lake Mashu" and is shipped to Tokyo, making a profit and contributing to the regional economy (See **Figure 3-1**).

Figure 3-1: Mango Cultivation in Teshikaga Town
(Photographed by Engineering Association)

Source: Okumura Tadahiko (2018): Case Study of Binary Power Generation and Hot Water Utilization, Geology, and Survey, No. 2, 2018, pp. 19-24

Another example of fruit cultivation is banana seedlings at the "Okuhida Farm" at the Okuhida Onsen in Gifu Prefecture. At an altitude of 800 m above sea level, hot spring water with an average temperature of 65°C and 25L/min flows into a waterway in the greenhouse and provides internal heat throughout the year. Because edible bananas are sold at low prices, ornamental banana seedlings are directly sold through the internet and are a source of revenue. (See **Figure 3-2**)

Figure 3-2: Banana Seedling Cultivation in Okuhida Farm
(photographed by Engineering Association)

Source: Okumura Tadahiko (2018): Case Study of Binary Power Generation and Hot Water Utilization, Geology, and Survey, No.2, 2018, pp. 19-24

Shiitake mushrooms are cultivated by the "Adonis Co., Ltd." in the Hotta hot spring district in Beppu, Oita Prefecture. A greenhouse was built to cultivate shiitake mushrooms using grants from the Ministry of Economy, Trade and Industry's geothermal development and promotion project. (See **Figure 3-3**) Oita prefecture is famous for its shiitake mushrooms and cultivation techniques. This method of growth is evaluated as being highly productive.

Figure 3-3: Shiitake cultivation at Adonis Co., Ltd.
(Photograph by Engineering Association)

Source: Okumura Tadahiko (2018): Case Study of Binary Power Generation and Hot Water Utilization, Geology, and Survey, No.2, 2018, pp. 19-24

Chrysanthemums are a good example of flower cultivation carried out by Oita Prefectural Agricultural Research Division Floriculture Group in Beppu. This center also received a subsidy for geothermal development and promotion and rebuilt five greenhouses that are now environmentally controlled. Steam of about 120°C is directly sent from the source to the greenhouses to heat them during the winter months. All of the hot water discharged from the greenhouse is provided free of charge to neighboring hot spring associations.

Source: Revised from Okumura Tadahiko (2018): Case Study of Binary Power Generation and Hot Water Utilization, Geology, and Survey, No.2, 2018, pp. 19-24
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

Steam is used for heating and also for disinfecting test research fields. Steam is directed to a target field by a fire hose, buried in the field with an iron pipe with open holes. Soil and materials brought by farmers (about 50 cases a year) are also disinfected free of charge (**Figure 3-4**) (Oita prefecture, 2018).

Source: Oita Prefecture Commerce and Labor Department New Industry Promotion Office (2018): Renewable Energy Top Runner Efforts on the Utilization of Geothermal Resources in Oita Prefecture, Geothermal Technology, Vol. 43, Nos. 3 & 4, pp. 23-27

Figure 3-4 Disinfection of Soil and Materials by Steam Sterilization Tank

Source: Oita Prefecture Commerce and Labor Department New Industry Promotion Office (2018): Renewable Energy Top Runner Efforts on the Utilization of Geothermal Resources in Oita Prefecture, Geothermal Technology, Vol. 43, Nos. 3 & 4, pp. 23-27

3.2.2 Examples of onshore aquaculture use

Onshore aquaculture projects are being conducted nationwide on the basis that fish grow faster when cultivated in hot water, leading to higher productivity.

Examples of cultivated fish are tilapia, Japanese pufferfish, eel, turf, shrimp, and abalone. An example of tilapia aquaculture is at "Hotel Parkway" in Kawayu Onsen in Hokkaido. Since 1989, approximately 30,000 tilapias have been grown by using hot water of 64.2°C at 400L/min to maintain water temperature at not below 15°C (See **Figure 3-5**). Because of the high quality of the hot spring water, the tilapia are active and feed well. They can grow up to 800g within one year. Because their flavor and appearance resemble sea bream, they are offered under the brand name of "Mashudai" and are served at inns as sashimi or in "kamameshi," meaning the fish is cooked with rice in an iron pot.

"Dream Creation" in Nakagawa, Tochigi Prefecture is famous for tiger puffer fish farming. It has three aquaculture facilities. The first plant (60 tons) uses a closed elementary school. The second plant (48 tons) uses a vinyl house adjacent to the school. The third plant (250 tons) uses a heated pool. As the fish are kept highly active throughout the year in the warmed water, they grow faster and can be shipped in one year, whereas it usually takes one year and a half when they are cultivated in the sea.

An example of shrimp aquaculture is the cultivation of "Onitenagaebi, *Macrobrachium nipponense*," which are cultivated in an aquaculture facility constructed with subsidy funds from the Geothermal Development and Understanding Promotion Project. The Genki Up Tsuchiyu Co., Ltd., is located at Tsuchiyu Onsen, Fukushima city, Fukushima. As the cooling water of the binary power generation rises from about 10°C to about 21°C, it is sent to the aquaculture facility. The temperature is then raised to about 25°C by the heat exchanger and supplied to the aquarium (See **Figure 3-6**).

This cultivation technology was introduced from Hirosaki in Aomori prefecture. Tourists enjoy fishing the grown Onitenagaebi in a simple fishing pond and then have their catch grilled on the spot. There are plans to increase the number of aquariums in the future, and this is a good example of conducting regional promotion through onshore farming.

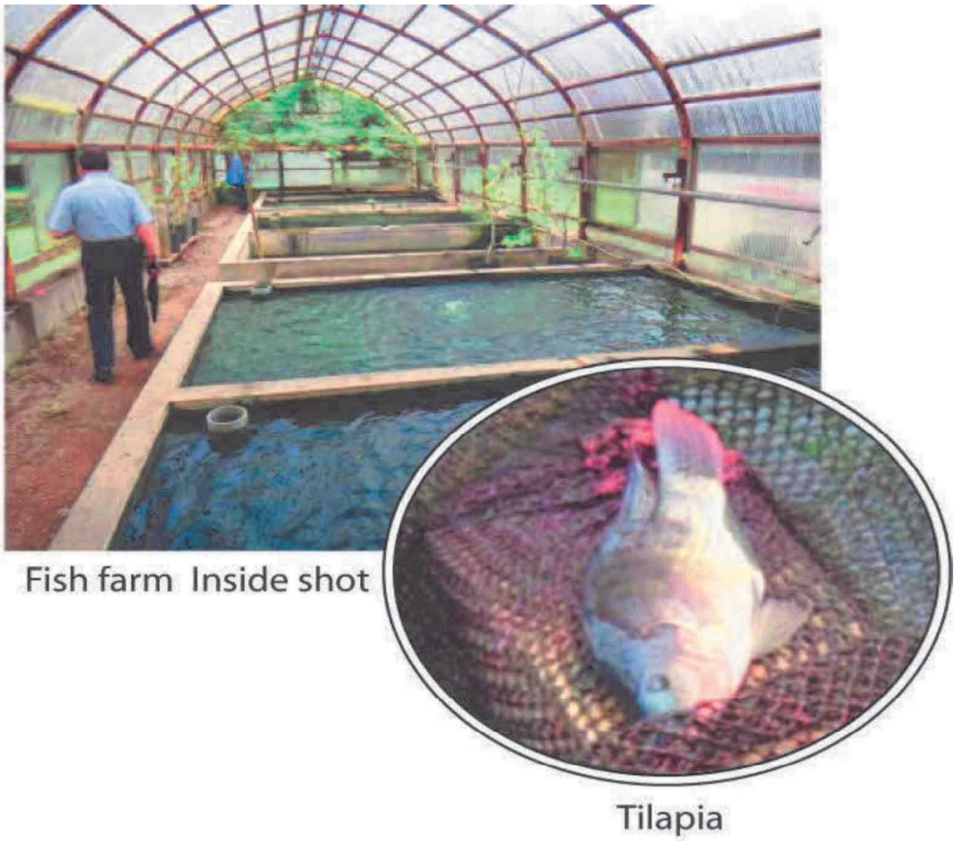


Figure 3-5: Tilapia Aquaculture at Hotel Parkway
(Photographed by Engineering Association)

Source: Okumura Tadahiko (2018): Case Study of Binary Power Generation and Hot Water Utilization, Geology and Survey, No.2, 2018, pp. 19-24
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

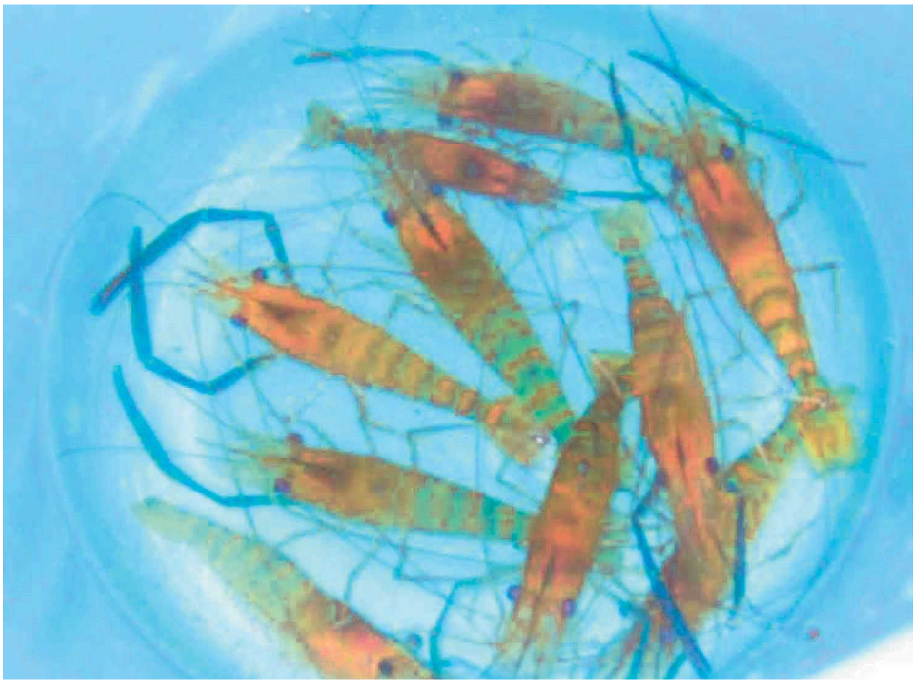


Figure 3-6: Tenagaebi aquaculture at Tsuchiyu Onsen
(Photographed by Engineering Association)

3.2.3 Examples of other uses

An example of using steam and hot water for heating buildings can be seen at Matsunoyama Onsen, Tokamachi, Niigata prefecture. There is a "ground furnace" that was built by using subsidies from the Geothermal Development and Understanding Promotion Project. At the inn, steam/hot water is used to heat the inside of the building, the floors and also to melt snow off of the roof. Additionally, it is used for cooking low-temperature processed brand pork known as "Tojibuta," a hot-spring specialty swine served as “Tojibutadon,” which is a bowl of rice cooked with the delicious pork.

Recently, Kurodaya in Kannawa hot springs in Beppu City, Oita Prefecture uses hot water and steam for both heating and cooling inside the inn (See **Figure 3-7**). This was also established with subsidies from the Geothermal Development and Understanding Promotion Project in 2014.
Kurodaya's absorption type water cooler/heater heats and also cools hot water, utilizing the heat when water evaporates. Because absorption type machines operate when there is a heat source, various heat sources such as waste heat from factories or private power generation equipment, biomass fuel can be utilized. (MITI Chugoku Bureau of Economy, Trade, and Industry, 2014)
For example, the standard specification value of the exhaust hot-water temperature of "Aeroace" is 88°C, and the temperature range is set to 70°C to 95°C (Yazaki Energy System, 2019). These types of air conditioning and heating facilities are also used in Senjokan of Naruyampei Onsen, Naruko Onsen-kyo, Nakayamadaira Onsen.

In "Hospital corporation symbiosis Kawayu no Mori Hospital" in Teshikaga, Hokkaido, hot water is used to heat the hospital. This was also established with the subsidy of the FY 2014 geothermal development understanding promotion project. Based on the business plan formulated in the previous fiscal year, an energy center was set up within the hospital premises utilizing existing hot spring sources, and hot water after power generation is utilized at multiple-stages. Organic vegetables and fruits are grown in the vinyl greenhouse utilizing hot spring heat
and provided as hospital food.

【References】

Tadahiko Okumura (2018): Case of binary power generation and hot water use, geology and survey, No. 2018 2, pp. 19 - 24 revised
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

MITI Chugoku Bureau of Economy, Trade and Industry,2014: on absorption type water cooler/heater
http://www.chugoku.meti.go.jp/info/densikoho/26fy/h2606/tweet2.pdf#search='吸収式冷温水機'

Yazaki Energy System Co., Ltd. (2019): Waste heat utilization absorption chiller/heater, hot water fired Aeroace
http://airconditioner.yazaki-group.com/product/aroace_ex_hw.html

Environmental business online (2016): uses of geothermal energy, 14 good examples for local community understanding, Grant from the Ministry of Economy, Trade, and Industry
https://www.kankyo-business.jp/news/013440.php

Figure 3-7: Kurodaya Absorption Type Water Cooler/Heater
(Photographed by engineering association)

3.3 Power plant utilizing hot springs

3.3.1 Small-scale binary power plants

Here are examples of small-scale binary power plants operating in Japan.

The Gotoen geothermal power plant in Beppu, Oita Prefecture is operated by Nishi-Nippon Geothermal Power Co., Ltd. It is a binary power plant using steam supplied by a hot spring source owner. Two installed micro binary power plants from the Kobe Steel Co., Ltd. have a rated output of 72kW. Operation started in March 2014. This plant sells all generated electricity to Kyushu Electric Power Co., Ltd., using the FIT program. This is a successful new business scheme in which the steam fee is recovered by using the income earned by FIT.

Because of Gotoen power plant's smooth operations, the Yuyama geothermal power plant, of the same scale, was also built in Beppu. A total of four micro binary plants are now generating and selling electricity in the area (See **Figure 3-8**).

Cosmotec Co., Ltd., which engages in space development, constructed a Cosmotec Beppu binary power plant in Beppu, Oita Prefecture as a new project. Four "Thermapower 125 MT" of Daiichi Sogo Co., Ltd., with a rated output of 125 kW were set up and started operation in November 2014, selling all generated electricity to Kyushu Electric Power Co., Ltd., using the FIT program. Here as well, the steam is supplied from the Beppu Spa Service Co., Ltd., the source owner. The steam usage fee is recovered by the earned income.

The first binary power plant was built in Yurihama, Tottori Prefecture in the Chugoku and Shikoku region. The business entity was "Kyowa Construction Consultant Co., Ltd." a construction consultant in Yonago, Shimane prefecture. Additionally, a part of the construction cost for the power plant was subsidized by Tottori prefecture and the town of Yurihama. Hot water, at 85°C, is supplied from the hot spring management cooperative, and the hot water usage fee is countered by profits from the FIT income. One "Heat Recovery HR 20W - 20 A" with a rated output of 20 kW is manufactured by IHI rotary machine engineering Co., Ltd., and was installed (See **Figure 3-9**).

The biggest binary power plant was constructed in Tsuchiyu Onsen-machi, Fukushima Prefecture, in the northern Tohoku region. Because the region was damaged by the Great East Japan Earthquake in 2011, Genki UP Tsuyutsu Co., Ltd., took a leading role and started to revitalize the town with binary power generation and heat utilization facilities, aiming at reconstruction after the earthquake. Steam was supplied from the source owned by Tsuchiyu Onsen Tourism Association, and the binary power plant was constructed with a guarantee from the Oil and Gas-Metals and Mineral Resources Organization (JOGMEC). JFE Engineering Co., Ltd., which is affiliated with Ohmat Corporation, constructed a binary power plant with a rated output of 440 kW. Operations started in November 2015. The total amount generated is sold through FIT. Among the binary power plants nationwide, the calendar day utilization rate is the highest at around 91% (See **Figure 3-10**).

Geothermal Development & Investment Inc. built the Sanko geothermal development binary power plant operated by Sanko Denki Co., Ltd. before cooperating with the Electra Therm Corporation. Steam is supplied from a source owner, and the steam usage fee is paid using FIT revenue. One "Power + Generator Power + 4400" from Electra Therm with a rated output of 65 kW has also been installed. It uses an air-cooling method and sells its entire generated volume using the FIT program.

【Reference】

Tadahiko Okumura (2018): Case of binary power generation and hot water use, geology and survey, No. 2018 2, pp. 19 - 24 revised
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

Figure 3-8 Yuyama Geothermal Power plant

Source: Oita Prefecture Energy Industry Society (2016): Oita Prefecture Energy Industry, 2016 Latest Version Brochure
http://oita-energy.jp/upload/2016Latest Version Brochure .pdf

Figure 3-9 Yurihama Geothermal Power plant

Source: Kyowa Building Consultant Co., Ltd. (2018): Yurihama Geothermal Power plant
http://kyouwacc.com/business/chinetsu-hatsuden

Figure 3-10 Tsuchiyu Onsen #16 Source Binary Power plant

Source: Genki Up Tsuchiyu Co., Ltd. (2018): Tsuchiyu Onsen #16 Source Binary Power plant

3.3.2 Hot-spring Power plants

(1) Types and characteristics of hot- spring power generation

Three methods of hot spring power generation are flash power generation, binary power generation, and steam power generation. Besides these methods, there is a power generation method that converts thermal energy into electric energy using a thermoelectric element, but because its output is small, it is not mentioned in detail here. Flash power generation has been used for large-scale geothermal power generation using hot spring steam to generate electricity from a rotating turbine. Even with hot-spring power generation, this method can be applied if enough steam can be obtained. Hot spring hotels in Kyushu introduced hot spring power generation by flash power generation and effectively utilized the steam of about 130°C to 160°C that was being released.

Binary power generation uses hot water or steam at about 70°C to 150°C to heat a medium whose boiling temperature is lower than water in order to generate high-pressure steam. This method is characterized by generating electricity with hot water at 100°C or less. Hydrocarbon gas (pentane), inert gas (substitute freon), or ammonia water are used as the medium. In recent years, examples of output have reached from several tens to several hundred kilowatts using inert gas to create high-pressure steam.

Steam (Yukemuri) power generation is a new power generation method that uses a boiling spring (a mixture of hot water and steam) that is discharged at around 100°C to 150°C. Hot water and steam are converted into a jet flow to rotate the turbine. A second turbine is further rotated using the steam after it passes through the first turbine. Power generation efficiency is increased by generating power with two turbines. There is no need to install cooling towers or heat exchangers because the structure of the equipment is simple, and cooling the water, which is required with flash power generation and binary power generation, is unnecessary. Binary power generation can also be carried out with hot water at 90°C or higher, after performing steam power generation if the installation has a cooling tower and cooling water can be secured.

Temperatures and yield amounts of hot springs vary from region to region. With the addition of steam power generation to conventional flash power generation and binary power generation, it has become possible to select a power generation method that is suitable for varying hot spring source conditions, and it is expected that suitable locations for hot spring power generation will be expanded and efficiency will be improved in the future.

Source: Masahiro Endo (2015): Hot spring power generation - renewable energy coexisting with hot spring resources -, survey and information - ISSUE BRIEF-, No. 845
http://dl.ndl.go.jp/view/download/digidepo_8943330_po_0845.pdf?contentNo=1

(2) Current status of hot- spring power generation

Initial hot-spring power generation was centered on facilities using flash power generation of a 1,000-kilowatt scale. Binary power generation using from dozens to hundreds on the kilowatt scale rapidly increased after the FIT program was introduced. In the future, the introduction of binary power generation is expected to proceed as well as hot-spring steam (Yukemuri) power generation. Oita Prefecture has the largest number of hot-spring power generation locations and is considered to be highly suitable for hot-spring power generation using existing hot-spring wells because of the many source wells in proportion to the geothermal resource quantity. Moreover, Oita prefecture has the greatest number of sources with hot water temperatures of 42 ℃ or more, as well as the greatest amount of steam gas in Japan.

Table 3-1 shows examples of the main introduction of hot- spring power generation. Not included in **Table 3-1**, Oita prefecture established an electricity generation utility as a practical power plant under the Oita Prefectural Agricultural Research Division Floriculture Group and sells the power. Steam and hot water from the hot spring sources on the premises are supplied to the research greenhouses for heating and throughout the neighborhood for bathing. A portion of the source steam (Yukemuri) is used for power generation. This plant is a No.2 practical generator and the No.1 is used for the sale of electricity by Geothermal World Industry Co., Ltd., which is the sales operator of this facility.

【References】

Masahiro Endo (2015): Hot spring power generation - renewable energy coexisting with hot spring resources -, survey and information - ISSUE BRIEF-, No. 845
http://dl.ndl.go.jp/view/download/digidepo_8943330_po_0845.pdf?contentNo=1

Masato Suzuki・Yosuke Takahira・Tomomi Shibuya(2016： New entry trends in binary power generation business and direction of future utilization of geothermal energy, Nikkei Research Laboratory Monthly Report 2016.5
https://www.jeri.or.jp/membership/pdf/research/research_1605_01.pdf

Table 3-1 Examples of the Main Introduction of Hot- spring Power Generation

Names	Location	Operators / Steam & hot-water suppliers	Unit	Installed capacity (kW)	Start	System
Kokonoe	Kokonoe, Oita	Makinoto Cooperation Co., Ltd.	1	990	H12.12.1	SF
Suginoi	Beppu, Oita	Suginoi Hotel	1	1900	H18.4.1	SF
Kirishima Kokusai Hotel	Kirishima, Kagoshima	Daiwabo Kanko Co., Ltd.	1	100	H22.11.1	SF
KA Continue	Beppu, Oita	KA Continue Co., Ltd.	1	72	H25.1.17	B
Gotoen	Beppu, Oita	West Japan Geothermal Power Corporation	2	144	H26.1.17	B
Shichimi Onsen Keizanntei Binary	Takayama, Nagano	Yagoyama Solar Limited Liability Company	1	20	H26.4.3	B
Yumura Onsen Kanko Koryu Center Yakushiyu Onsen Binary	Shinonsen, Hyogo	Shinonsen machi, Hyogo / Yuzaisanku, shinonsen	2	40	H26.4.10	B
Tatara Daiichi	Beppu, Oita	Chinetsu Kogyo Co., Ltd.	1	72	H26.7.8	B
Ogunimatsuya	Oguni, Kumamoto	Ogunimatsuya Power Generation Station Limited Liability Company	3	60	H26.7.29	B
Yuyama	Beppu, Oita	West Japan Geothermal Power Corporation	2	144	H26.10.3	B
Cosmotec Beppu Binary	Beppu, Oita	Cosmotec Co., Ltd. / Beppu Spa Service Co., Ltd.	4	500	H26.11.30	B
Kamenoi	Beppu, Oita	Chinetsu World Kogyo Co., Ltd.	1	11	H27.2.27	T
Fino Binary	Beppu, Oita	Fino binary power plant L.L.C./ Beppu Spa Service	2	250	H27.6.30	B
Yufuin Forest Energy Binary	Yufu, Oita	Yufuin Forest Energy Co., Ltd.	1	125	H27.7.30	B
Minami Tateishi Onsen-nestu	Beppu, Oita	Heiwa Construction Co., Ltd.	2	60	H27.8.5	B
Obama Onsen Binary	Unzen, Nagasaki	Daiichi Obana Binary Power Generation station Limited Liability Company	1	135	H27.9.2	B
Kyowa Chiken Consultant Yurihama	Yurihama, Tottori	Kyowa Chicken Consultant Co., Ltd. / Togo Onsen Management Cooperative Association	1	20	H27.10.5	B
Tsuchiyu Onsen Unit 16 Source Binary	Fukushima, Fukushima	Tsuchiyu Onsen Energy Co., Ltd./ Yuyutsuchiyu Onsen Management Cooperative Association	1	440	H27.11.16	B
Abe Medical Clinic	Beppu, Oita	Abe Medical Clinic	1	20	H27.12.21	B
Hotel Sun Valley Binary	Nasu, Tochigi	Hotel Sunvalley Nasu	1	20	H28.3.18	B
Sanko Geothermal Development Binary	Beppu, Oita	Sanko Denki Co., Ltd.	1	65	H28.4.15	B
PPSN Binary	Beppu, Oita	PPSN Co., Ltd./ Beppu Spa Service Co., Ltd.	1	125	H28.7.1	B
SUMO POWER	Beppu, Oita	SUMO POWER Co., Ltd./ Beppu Spa Service Co., Ltd.	1	125	H28.7.1	B
NNS Power	Beppu, Oita	NNS Power Co.,Ltd./ Beppu Spa Service Co., Ltd.	1	125	H28.10.26	B
Mashuko Onsennetsu	Teshikaga, Hokkaido	Kokushokankoukai Inc.	1	125	H28.11.2	B
HTB Energy Beppu Onsen Hoyo Land	Beppu, Oita	HTB Energy Co., Ltd.	1	72	H28.9.9	B
Toyako Onsen Binary	Toyako, Hokkaido	Toyako Onsen Management Cooperative Association	1	72	H29.3.10	B

Cont'd

Names	Location	Operators/Steam & hot water suppliers	Unit	Installed capacity (kW)	Start	System
Makino Power Plant	Beppu, Oita	—	—	125	H29.6	B
Yufuin Forest Energy Binary 2 Power Plant	Yufu, Oita	—	—	72	H29.6	B
Okue Hot Spring Geothermal Binary Cycle Power Plant	Yufu, Oita	—	—	72	H29.6	B
Hot Lagoon Oita Geothermal Power Plant	Kokonoe, Oita	—	—	72	H29.7	B
BLD Binary Power Plant	Beppu, Oita	—	—	250	H29.7	B
Kokonoe Noya District Binary Power Plant	Kujyu, Oita	—	—	72	H29.8	B
Ciba Power Plant	Beppu, Oita	—	—	250	H29.9	B
Chiba HD Power Plant	Beppu, Oita	—	—	250	H29.9	B
GRACE Power Plant	Beppu, Oita	—	—	125	H29.9	B
Kijyu Power Plant	Beppu, Oita	—	—	125	H29.9	B
Narasaki Mikio Power Plant	Beppu, Oita	—	—	125	H29.9	B
VEP Energy Power Plant	Beppu, Oita	—	—	125	H29.9	B
RE—ENERGY Geothermal Power Plant	Beppu, Oita	—	—	125	H29.9	B
RENAVIS Power Plant	Beppu, Oita	—	—	125	H29.9	B
Rena Power Station No.1 Power Plant	Beppu, Oita	—	—	250	H29.9	B
Okuhida Binary Power Plant	Takayama, Gifu	—	—	72	H29.11	B
Le Lave Power Plant	Beppu, Oita	—	—	72	H29.11	B
P—POWER Power Plant	Beppu, Oita	—	—	250	H29.11	B
Okushiri Geothermal Power Plant	Okushiri, Hokkaido	—	—	250	H29.12	B
NIS Binary Power Plant	Beppu, Oita	—	—	250	H29.12	B

Power Generation System：SF（Single Flash）B（Binary）T（Total Flow（Yukemuri））

【Created based on Thermal Power Nuclear Power Technical Association (2018)】

Source: Thermal Power Nuclear Power Technical Association (2018): Current situation and trend of geothermal power generation 2017

3.4 Protection of hot spring resources

Hot springs are a valuable resource and a vital part of public welfare. To assure appropriate use, the protection of hot spring resources has been promoted by the Ministry of the Environment and both prefectural and city governments based on hot spring law.

There is a risk of public health problems that can arise from the following conditions:
① possible exhaustion due to disorderly excavation or collection and/or a decrease in the amount of waste discharged
② possible disaster due to combustible natural gases
③ possible offering for public use without adequate information on hot springs

Therefore, in developing hot spring resources, “Hot Spring Protection," "Preventing Disasters with Hot Spring Collection," and "Appropriate Use of Hot Springs" were stipulated by the Hot Spring Act.

3.4.1 Laws

Table 3-2 shows laws, enforcement orders, and enforcement regulations for hot springs.

Table 3-2 Laws, Enforcement Orders, and Enforcement Regulations for Hot Springs

Name	Last revised
The Hot Spring Act: Law No. 125 of July 10, 1948	Law No.105, August 30, 2011
Enforcement ordinance of hot spring law: Decree No. 25 of March 9, 1984	Decree No. 364 of November 28, 2011
Enforcement regulations for hot spring law: Ministry of Health Ordinance No. 35 of August 9, 1948	Minister of the Environment Ordinance No. 21 of July 6, 2012

Source: Ministry of the Environment (2019): Ministry of the Environment> Policy Areas / Administrative Activities> Policy Field List> Natural Environment / Biodiversity> Protection and Use of Hot Springs> Related Materials> Laws, Cabinet Orders, Ministerial Ordinance https://www.env.go.jp/nature/onsen/pdf/2-5_p_1.pdf

The purpose of the hot spring law is to protect hot springs, to prevent disasters caused by flammable natural gas caused by collection at hot springs, to make appropriate use of hot springs, and to contribute to the promotion of the public welfare. The following matters are stipulated in "Chapter 2 Protection of Hot Springs" as shown in **Table 3-3.**

Table 3-3 Contents on Protection of Hot Springs in Hot Spring Law

Name	Title
Article 3	Permitting excavation of land
Article 4	Criteria for permission
Article 5	Effective duration of permission
Article 6	Merger and division of legal entities who have obtained permission for excavation of land
Article 7	Inheritance of persons who received permission for land excavation, change of facility for excavation
Article 8	Notification of Completion or Abolition of Construction
Article 9	Cancellation of permission, order of emergency measures
Article 10	Restoration of original status
Article 11	Permit of excavation or power equipment
Article 12	Order concerning restrictions on collection of hot springs
Article 13	Consultation with the Minister of the Environment
Article 14	Order for measures to those who drilled the land for other purposes

Source: Ministry of the Environment (2019): Ministry of the Environment> Policy Areas / Administrative Activities> Policy Field List> Natural Environment / Biodiversity> Protection and Use of Hot Springs> Related Materials> Laws, Cabinet Orders, Ministerial Ordinance
https://www.env.go.jp/nature/onsen/pdf/2-5_p_1.pdf

3.4.2 Guidelines

The latest guidelines on the protection of hot spring resources are "Guidelines on the Protection of Hot Spring Resources (Revised April 2014)" and "Guidelines on Protection of Hot Spring Resources (Geothermal Power Generation Relations) (Revised October 2017)." Both guidelines derived from the Natural Environmental Agency within the Ministry of the Environment.

(1) Guidelines on the protection of hot spring resources

The aim of this guideline is to establish criteria for judgment with regard to non-permissible reasons for hot spring excavation. Specific items are across-the-board regulations, by region. These involve restricted area settings, distance control from existing sources, the influence survey method for individual judgment and the judgment of suitability for public interest infringement.

【History of creating guidelines 】

Prefectural and city governments lack scientific information and data on the amount of hot spring resources and the influence on the yield of hot spring water caused by extraction. Thus, it is difficult to make a non-permission or a restriction order on an inadequate scientific basis. We have been engaging in protecting hot spring resources and making use of regional characteristics by independently setting spa protected areas according to the outline. These include restricting the distance from the existing source, restricting the amount of lift while taking into consideration the impact on neighboring sources. In February 2007, the "Central Environment Council (Natural Environment Subcommittee Hot Spring Subcommittee)" considered measures on the protection of hot spring resources and the information on the ingredients of hot springs based on consultation with the Ministry of the Environment. The subcommittee asked the Ministry of the Environment to create concrete and scientific guidelines on the contents of the criteria for drilling by a new business operator and the permission of local power plants. This guideline ensures that prefectural and city governments can follow it as a reference in defining ordinances and outlines for hot spring resource protection.

In light of this proposal, the Ministry of the Environment issued guidelines in March 2012 on the protection of hot spring resources as a means of preserving resources to enable sustainable use for future generations.

Source: Ministry of the Environment, Ministry of Nature and Environment (2014): Guidelines on Protection of Hot Spring Resources (Geothermal Power Generation Relations) (Revised), October 2018
https://www.env.go.jp/nature/onsen/pdf/2-5_p_3.pdf

(2)Guidelines on the protection of hot spring resources (geothermal power generation related)

These were formulated in March 2012 as guidelines on geothermal power generation related to the protection of hot spring resources for drilling and for the development of geothermal power generation so that the introduction of renewable energy is promoted while protecting hot spring resources. Specifically, the data obtained at each stage of excavation is taken as material for judging the influence on hot spring resources and shows the judgment method upon which it is based. This guideline is positioned as a separate volume of the above "Guidelines on the Protection of Hot Spring Resources (Revised April 2014)."

【Reference】

Ministry of the Environment, Agency of Nature and Environment (2017): Guidelines on the protection of hot spring resources (geothermal power generation related) (revised), October 2017
https://www.env.go.jp/nature/onsen/pdf/2-5_p_6.pdf

3.4.3 Regulations on geothermal resources

Information on ordinances for compliance when conducting geothermal development is published on

JOGMEC's website. A list of regulations for municipalities that were created based on that information (as of January 2018) is shown in **Table 3-4**. However, the outline for Beppu, Kokonoe, and Hachijo are targeted not only for geothermal development, but also for renewable energy.

Table 3-4 List of Municipal Ordinances Concerning Geothermal Development

Prefecture	Municipality	Ordinances	Effective Date
Hokkaido	Teshikaga	Ordinance on Protection and Utilization of Teshikaga-cho Geothermal Resources	Jan. 23, 2018
Tokyo	Hachijo	Hachijo Basic Ordinance on Regional Renewable Energy	April 1, 2014
		Hachijo Guideline on Renewable Energy Business	April, 2014
Oita	Beppu	Beppu Outline on Preliminary Procedure, etc. of Introduction of Regional New Energy	Sept. 22, 2014
		Beppu Ordinance for the Coexistence of the Community and the Hot-spring Power Generation, etc.	May 1, 2016
Oita	Kokonoe	Kokonoe Guidelines on Facility Installation Business for Renewable Energy Power Generation	Dec. 1, 2014
		Kokonoe Ordinance on Protection and Utilization of Geothermal Resources	Dec. 18, 2015
Kumamoto	Minamiaso	Minamiaso Ordinance Concerning the Utilization of Geothermal Resources	Dec. 12, 2015
Kumamoto	Oguni	Oguni Ordinance on Proper Use of Geothermal Resources	Jan. 1, 2016
Kagoshima	Ibusuki	Ibusuki Ordinance on Protection and Use of Hot-spring Resources	April 1, 2015
Kagoshima	Kirishima	Kirishima Ordinance on Power Generation Project using Hot springs	Oct. 5, 2015

【Created based on JOGMEC(2018) 】

Source: JOGMEC (2018): HOME> Local Government Information> Local Government's>Geothermal Ordinance Related Information
http://geothermal.jogmec.go.jp/local/info.html

(1) Contents of the Ordinances

In the geothermal resource ordinance, the positioning of geothermal resources is shown as municipal-specific property, city and citizen's shared resources. The target business operators are business entities that utilize hot springs to conduct geothermal power generation.

The target businesses to be engaged in geothermal power generation center their work on new drillings, alternative drillings, and additional drillings. Included are those businesses that utilize the steam and hot water generated after initial power generation. The responsibilities of business operators and the authority of the municipality are indicated in the ordinances and summarized as follows.

(i) Obligations of business operators:

・Hold local briefing sessions

・Submit a business plan including a monitoring survey plan
・Take necessary measures when, due to power generation projections, changes in the amount of discharge in surrounding hot spring output are recognized (Kokonoe, Minamiaso, and Oguni)
・Notify the start and the completion of business operations

(ⅱ) Authority of municipalities:

・Councils and committees (hereinafter referred to as "councils") shall be set up and will examine business plans. Municipal mayors shall decide whether to accept and give consent, taking into consideration the opinion of the council (Kokonoe, Minamiaso, Oguni, Ibusuki, and Kirishima)
・On-site inspections and recommendations to operators can be carried out. If and when operators are found in non-compliance with the agreed upon measures, those company names can be announced publicly.
・Conclusion of agreements on environmental conservation can be requested from operators. (Ibusuki-shi, Kirishima-shi)

Table 3-5 and **Table 3-6** show the outline of the ordinances of each municipality excluding Teshikaga-cho and Hachijo-machi.

Table 3-5 Outline of Ordinances etc. of Each Municipality (1)

	Beppu, Oita		Kokonoe, Oita	
Name	Beppu - Outline on Preliminary Procedures of Introduction of Regional New Energy	Beppu Ordinance for the Coexistence of the Community and Hot-spring Power Generation	Kokonoe- Guidelines on Facility Installation Business for Renewable Energy Power Generation	Kokonoe -Ordinance on Protection and Utilization of Geothermal Resources
Implementation Date	Sept. 22, 2014	May 1, 2016	Dec. 1, 2014	Dec. 18, 2015
Target businesses	Solar power generation (500 W or more) Wind power generation (20kW or more) Geothermal•Hot-spring power generation (10kW or more) Hydropower generation (20kW or more) Biomass power generation (10kW or more)	Hot-spring power generation Other power generation equipment and incidental facilities using geothermal energy	Solar power generation (50kW or more) Wind power generation (20kW or more) Hydro power generation (20kW or more) Hot-spring power generation General biomass power generation etc.	Geothermal power generation business (※) (※) Projects that utilize existing wells and do not cause a change in the amount of discharge before and after the project will be handled by the left outline
Main obligation of business operators	○ Hold a local briefing session ○ Apply for an advance consultation ○ Perform and report monitoring ○ Notify start and completion of construction	○ Hold a local briefing session ○ Explain and obtain consent from the water users ○ Inspect to predict the influence on the surrounding environment ○ Develop a noise prevention plan ○ Notify the start of prior consultation and report its completion ○ Perform and report monitoring ○ Notify start and completion of construction	○ Hold a local briefing session ○ Submit the project plan and the contract for installing the power generation facility ○ Perform and report monitoring ○ Report completion of the start of construction	○ Hold a local briefing session ○ Submit the project plan and the contract power generation facilities ○ Perform and report monitoring ○ Take necessary measures when change in the discharge amount of surrounding hot springs is recognized due to power generation projects ○ Notify the start and the completion of the project
Main responsibilities of municipalities	○ Listen to opinions from stakeholders regarding answers to prior consultation & carry out on-site investigations ○ Provide guidance and advice to business operators ○ Publish information on energy conservation introduction cases and achievements	○ Approve completion of preliminary consultation If necessary, issue consent form for procedures concerning various laws and ordinances ○ Carry out investigations and provide recommendations ○ In case of not complying with the measures, disclose the facts. Freeze the procedure for other projects carried out by the business operator until improvement occurs	○ Inspect business operators ○ Provide guidance and advice to business operators ○ Take measures and provide advice to business operators	○ Establish a geothermal power generation project review committee ○ Give a consent form by the mayor for the business plan ○ Provide recommendations to business operators and conduct on-site inspections (In case of non compliance with greed upon measures, & disclose the facts.)

Source: Study Group on Promotion of Geothermal Power Generation (2016): Partial revision of the present situation and measures concerning geothermal resource development (January 2016) http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/society/pdf/160127.pdf

Table 3-6 Outline of Ordinances of Each Municipality(2)

	Minamiaso, Kumamoto	Oguni, Kumamoto	Ibusuki, Kagoshima	Kirishima, Kagoshima
Name of the ordinances	Minamiaso Ordinance Concerning the Utilization of Geothermal Resources Scope of application: Western Mt.Aso area (Minamiaso-mura Oaza Kawayo, Oaza Nagano)	Oguni Ordinance on Proper Use of Geothermal Resources	Ibusuki Ordinance on Protection and Use of Hot-spring Resources	Kirishima Ordinance on Power Generation Project Using Hot springs
Implementation date	Dec. 12, 2014	Jan. 1, 2016	April 1, 2015	Oct. 5, 2015
Target businesses	Geothermal and hot spring power generation business utilizing geothermal resources	Business to generate electricity utilizing geothermal resources	Geothermal power generation (10kW or more)	Power generation business using hot springs or business utilizing steam and hot water generated after power generation
Main obligation of operators	○ Hold local briefing session ○ Submit the project plan ○ Take necessary measures when change in the discharge amount of surrounding hot springs is recognized due to power generation projects ○ Notify start and completion of construction	○ Hold local briefing session ○ Submit the project plan ○ Take necessary measures when change in the discharge amount of surrounding hot springs is recognized due to power generation projects ○ Notify start and completion of construction	○ Hold local briefing session ○ Submit the project plan ○ Take necessary measures when change in the discharge amount of surrounding hot springs is recognized due to power generation projects ○ Perform monitoring ○ Conclude agreement according to city's request	○ Hold local briefing session ○ Submit the project plan ○ Perform and report monitoring ○ Notify start and completion of construction ○ Conclude agreement according to city's request
Main responsibilities of municipalities	○ Establish a council ○ Deliver a consent form for the business plan by the village mayor ○ Provide recommendations to business operators and conduct on- site inspections (In case of non- compliance with the measures, publicly disclose acts).	○ Establish a council ○ Deliver a consent form for the business plan by the village mayor ○ Provide recommendations to business operators and conduct on- site inspections (In case of non- compliance with the measures, publicly disclose acts).	○ Establish a council ○ Deliver a consent form for the business plan by the village mayor ○ Provide recommendations to business operators and conduct on- site inspections (In case of non- compliance with the measures, publicly disclose acts). ○ Request business operators to conclude agreement on environmental conservation	○ Establish a council ○ Deliver a consent form for the business plan by the village mayor ○ Provide recommendations to business operators and conduct on- site inspections (In case of non- compliance with the measures, publicly disclose acts). ○ Request business operators to conclude agreement on environmental conservation

Source: Study Group on Promotion of Geothermal Power Generation (2016): Present situation and measures concerning geothermal resource development (January 2016) http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/society/pdf/160127.pdf

(2) Restricted areas in Beppu - “Avoid Areas”

Beppu enacted the "Beppu City Ordinance for the coexistence of the community and hot-spring power generation," to ensure that the introduction of hot spring power generation would harmonize with the natural environment and coexist with local citizens. As of May 1, 2016, the date of enforcement, business operators of hot-spring power generation have been required to take necessary procedures specified in this ordinance based on prior consultation.

This ordinance was partially revised in June 2018 and enforced on October 1, 2018. It requires business operators conducting drilling for hot-spring power generation to avoid designated areas that require additional procedures before applying for permission. Operators must conduct, in advance, geothermal resource surveys and monitoring surveys before concluding agreements with municipalities.

【Reference】

Beppu city (2018): Ordinance for the coexistence of the community and hot-spring power generation
https://www.city.beppu.oita.jp/sangyou/environment/alternative_onsen.html

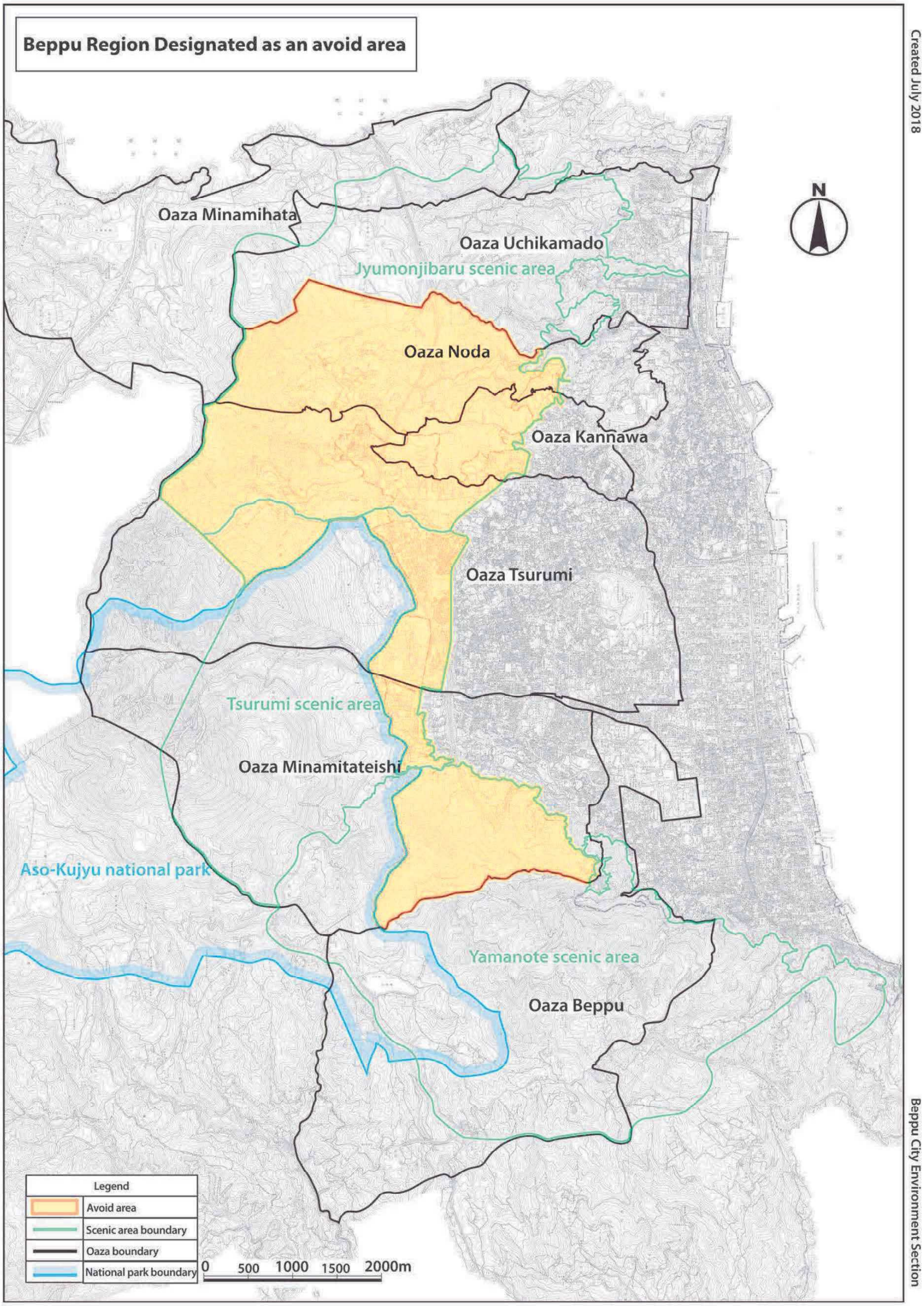


Figure 3-11 Beppu region designated as "Avoid Area"
Source: Beppu city environment section (2018): Partially revised map of Beppu regions designated as avoid areas
https://www.city.beppu.oita.jp/doc/sangyou/environment/avoid.pdf

(3) Revision of deliberation standards by Oita Prefecture Environmental Council

The Hot Springs Division (Chairman Yuki Yusa) of Oita Prefectural Environment Council revised the internal regulations that set deliberation standards for allowing hot spring drilling. This revision was done in order to expand the protected areas throughout the city aiming to protect the limited spa resources and leading to sustainable usage. This was the first time in 45 years, dating back to 1973, to expand the protected areas in the city. The updated regulations were implemented as of December 1, 2018.

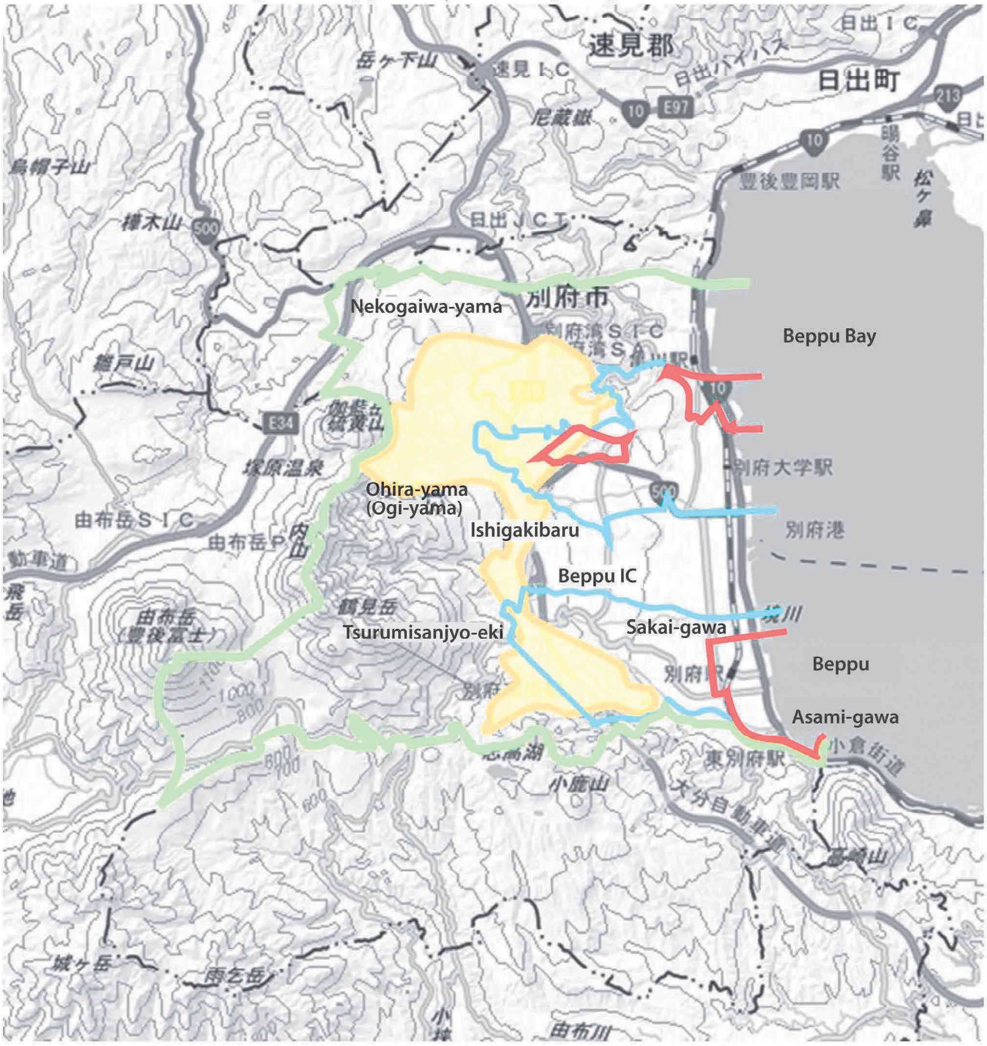
In protected areas in Beppu, new drilling is prohibited within 100 meters of the source and within 150 meters from the fumaroles (openings in or near a volcano, through which hot sulfurous gases emerge) and boiling springs. Alternative drilling to replace existing sources is possible. Until now, however, the designated areas have been in the southern protected areas including the Kitahama and Hamawaki districts and the northern protected areas including Kannawa. With this amendment, the designated areas are extended from the heat source of Garan-dake and Tsurumi-dake toward Beppu bay covering all areas of the basin. The whole area is now designated as “City Protected Areas.”

According to the Hot Springs Division and the Oita prefecture government, it is becoming impossible to secure hot springs of the same temperature in the whole city unless deeper excavation takes place. Some areas also show that temperatures have dropped. Future shortages are a concern due to limited resources; therefore, protected areas have been reconsidered.

【References】

Oita Godo Shimbun (2018): Protected area extends almost throughout Beppu city
https://www.oita-press.co.jp/1010000000/2018/08/11/JD0057197925

Change In Beppu City`s Hot Spring Protection Area



Indication	Designated area	Name	New drilling			Alternative drilling
			Possibility of drilling	Offset distance		
				Hot springs	fumeroles・Boiling source	
	Special protection area (No change)	Beppu southern special protection area Beppu Kamagawa special protection area Beppu Kannawa special protection area	will not admit	—	—	will admit
	Protected area (Before revision)	Beppu southern protected area Beppu northen protected area	will admit	100m	150m	will admit
	Protected area (After revision)	Protection area	will admit	100m	150m	will admit
	General area		will admit	60m	150m	will admit

* Map of Beppu region designated as "Avoid Area" Refer to Figure 3-11 for a detailed illustration.

Figure 3-12 Change in Beppu city's hot spring protection area
http://www.pref.oita.jp/uploaded/life/2036066_2261199_misc.pdf

4. Overseas Cases

4.1 Heat utilization and geothermal power generation in the world

4.1.1 Heat utilization

Figure 4-1 shows the usage ratio of the world heat utilization as of the end of December 2014. 55% of the direct use of geothermal energy is used for geothermal heat pumping (GHP); 20% is for baths and swimming pools, and 15% is used for heating (half of which is regional heating). The direct use rate per population is high in northern European countries such as Iceland, Sweden, and Norway. The direct use rate per area is the highest in Switzerland. The recent rate of increase is high in Thailand and Egypt. The most common usage is in 70 countries for bathing and pools, 45 countries for GHP, and 31 for greenhouses. The utilization rate is 20.7% for GHP; others are slightly higher, late 20's of overall average while average usage in industry use exceeds 50%. For direct use as a whole, 26.2 TOE/year (TOE: Tons of Oil Equivalent), geothermal power generation is 52.2 TOE/year, and direct use is equivalent to about half of geothermal generation as the annual oil replacement amount.

【References】

Kasumi Yasukawa et al. (2015): WGC 2015 Report 1 (Keynote, Recent State, Social Aspects, Drilling, EGS, Sustainability, Software, Innovation, Geothermal Heat Pump), The Geothermal Society of Japan, Vol. 37, No 3, pg.101-117
https://www.jstage.jst.go.jp/article/grsj/37/3/37_101/_pdf/-char/ja

John W. Lund and Tonya L. Boyd (2015): Direct Utilization of Geothermal Energy 2015 Worldwide Review, Proceedings World Geothermal Congress 2015

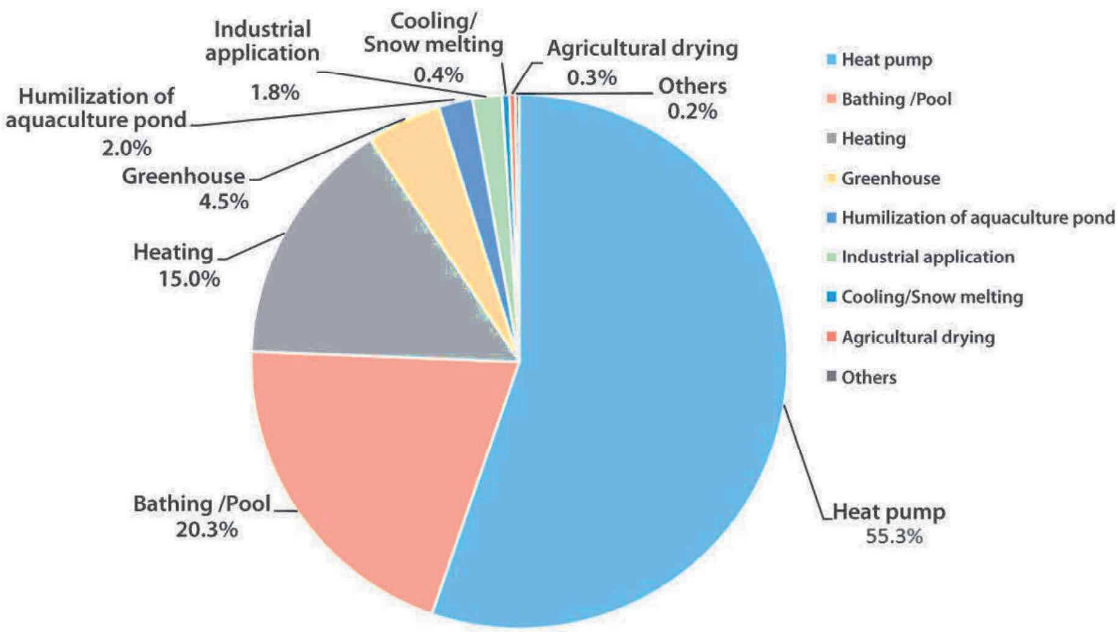


Figure 4-1 Ratio of Heat Utilization by Worldwide Applications
【As of the end of December, 2014】

【 Created based on the world heat utilization data of Lund and Boyd (2015) (Total: 587,786 TJ / yr)】

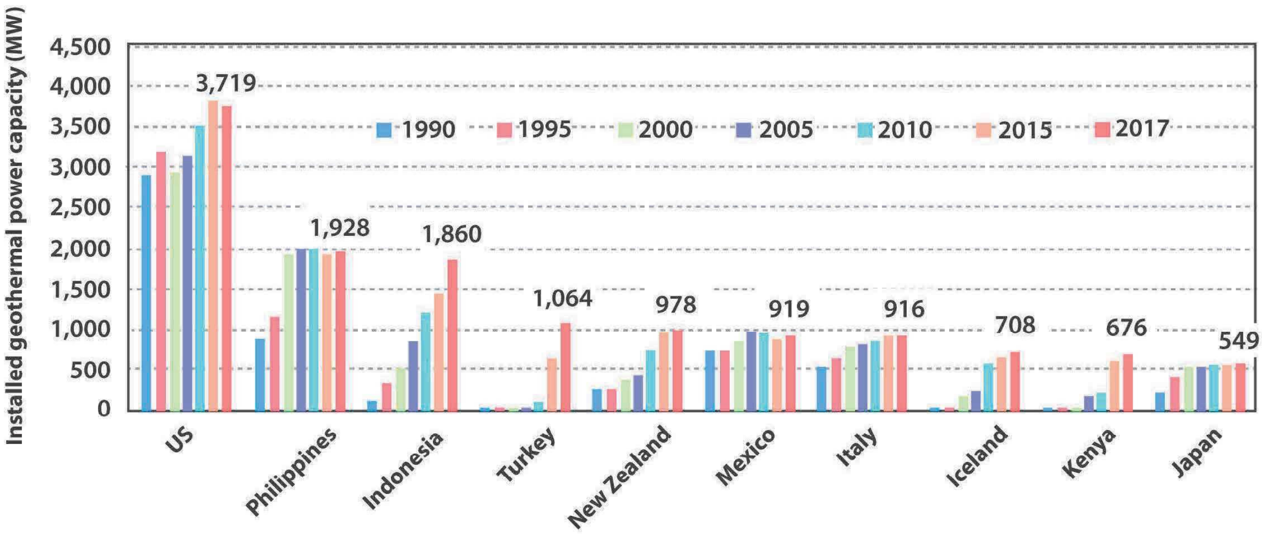
Source: John W. Lund and Tonya L. Boyd (2015): Direct Utilization of Geothermal Energy 2015 Worldwide Review, Proceedings World Geothermal Congress 2015

4.1.2 Geothermal power generation

Changes to installed geothermal power capacity in each country are shown in **Figure 4-2**. The capacity of the global geothermal power generation of 2017 reached 14.3GW. The growth of geothermal development in Indonesia, New Zealand, Iceland, and Kenya has been remarkable in recent years.
Japan's share of world installed geothermal capacity is around 4%, which is the tenth largest in the world after Iceland. The share of geothermal power generation in the total power generation of the whole world is very small (0.3% in 2017), but it plays an important role in some countries. For example, the ratio of geothermal power generation to total power generation capacity is over 40% in Kenya, over 25% in Iceland, and 18% in New Zealand.

【Reference】

BP (2018): Home / Energy economics / Statistical Review of World Energy / Renewable energy / Geothermal power
https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/renewable-energy.html/geothermal-power



【Created based on BP(2018)】

Figure 4-2 Changes in Installed Geothermal Power Capacity

Source: BP (2018): BP Statistical Review of World Energy, 67th edition, Renewable energy-geothermal
https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-renewable-energy.pdf

The following sections show the utilization of geothermal energy, including heat utilization and geothermal power generation, in the order of the largest amount of geothermal resources in major countries.

4.2 USA

4.2.1 Geothermal resources

Geothermal resources in the United States are distributed in western areas where volcanic activities and orogenesis activities abound. The San Andreas fault from California's Imperial Valley to the San Francisco region, the subduction zone off the coast of northern California, Oregon, Washington, and Cascade Volcanism are the sources of much of the geothermal activity in the United States.

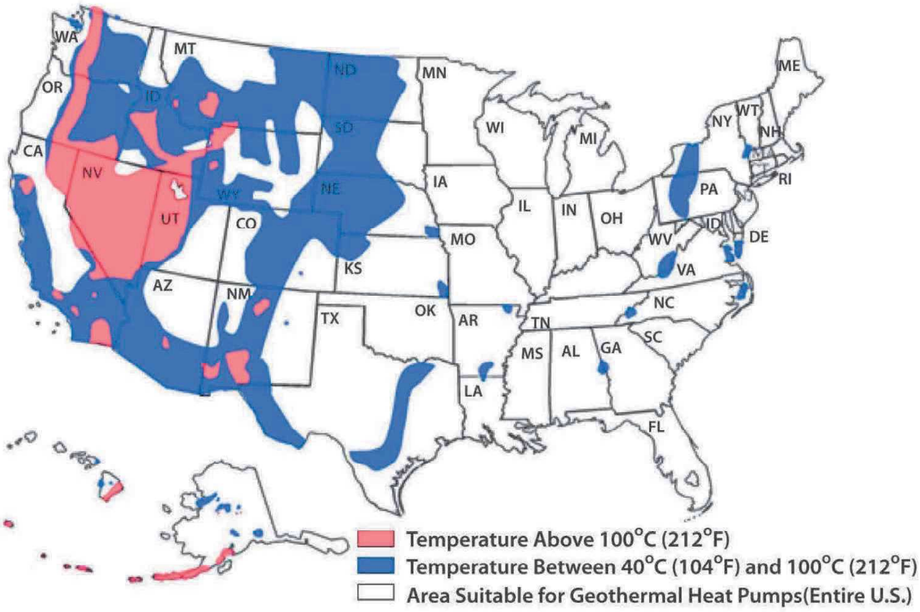


Figure 4-3 Geothermal Resource Map of the United States

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015

4.2.2 Heat utilization

The United States is one of the world's leaders in direct-use applications of geothermal resources. Its direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications, and ground-source heat pumps. The installed capacity is 17,416 MW_t and the annual energy use is 75,862 TJ or 21,074 GWh. The largest application is ground-source (geothermal) heat pumps (88% of the energy use), and the next largest direct-uses are fish farming and swimming pool heating. The geothermal heat pumps have been operated at an annual growth rate of 8% with 1.4 million units (12 kW size) in operation. Energy conservation, through the use of all geothermal energy, is the fuel oil (74.7 million barrels) equivalent of approximately 11.2 million tons annually, reducing air pollution (about 10 million tons of carbon) and 28 million tons of CO2 (compared with fuel oil.)

【References】

BP (2018): Home/Energy economics/Statistical Review of World Energy/Renewable energy /Geothermal power
https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/renewable-energy.html/geothermal-power

Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015
https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

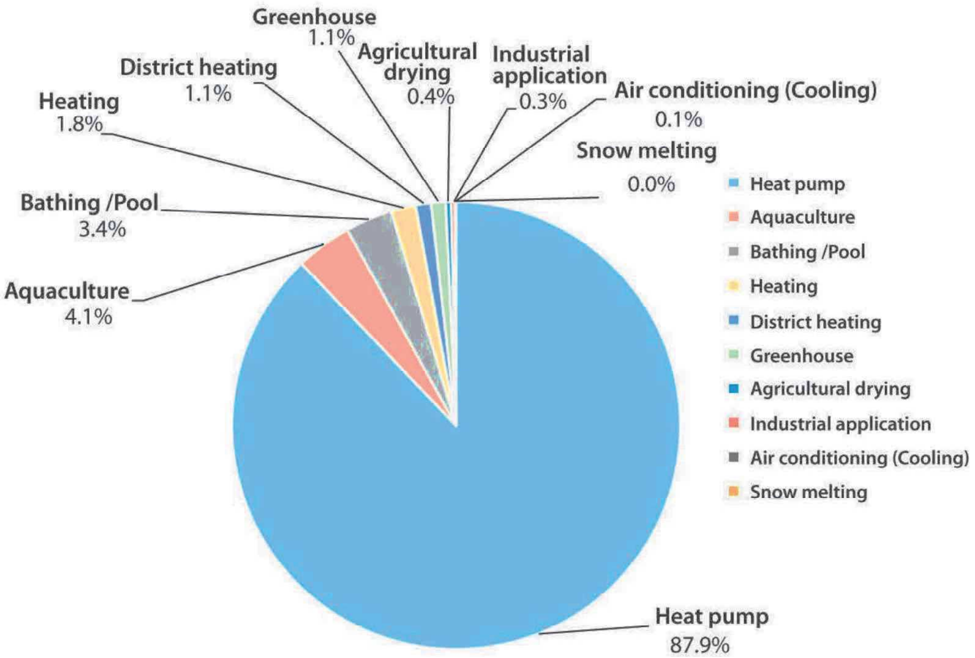


Figure 4-4 Ratio of Heat Utilization by Application in the United States
【As of the end of December, 2009】
【 Create based on Boyd et al. (2015) (Total: 75,862 TJ/yr)】

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015 https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

Table 4-1 shows the breakdown of heat utilization by application, excluding the geothermal heat pumps, as of the end of December 2014. Aquaculture fishery is top in both installed capacity and heat utilization whose utilization rate is as high as 69%. Next comes the bath/pool and the amount of heat utilization is large. Its utilization rate is extremely high at 72%. The installed capacity of heating buildings is the second largest, but due to its low utilization rate, the amount of heat used is about half that of bath/pool.

【Reference】

Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015 https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

Table 4-1 Heat Utilization in the USA (Excluding Geothermal Heat Pumps)

Use	Installed capacity (MW_t)	Annual energy use (TJ/yr)	Capacity factor (%)
Aquaculture fishery	141.95	3074.0	69
Bathing/Pool	112.93	2557.5	72
Heating (Buildings)	139.89	1360.6	31
District heating	81.55	839.6	33
Greenhouse	96.91	799.8	26
Agricultural drying	22.41	292.0	41
Industrial process heat	15.43	201.1	41
Cooling	2.31	47.6	50
Snow melting	2.53	20.0	25
Others	0.0	0.0	-
Total	**615.91**	**9,192,2**	**47**

【As of the end of December, 2014】

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015 https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

(1) Examples of aquaculture fishery

The main geothermal zone in the United States is located in the West Coast and Hawaii, but geothermal heat is used directly in the Midwest as well. Various types of cultivation using geothermal energy is carried out at 12 places in Idaho and in the Midwest. The most common example is tilapia, and other examples are catfish, snails, tropical fish, edible frogs, coral, and the like, among which the edible crocodile is famous (Neely, 2007). In **Table 4-1**, crocodiles are also classified as aquaculture fishery (original text: fish farming).

An example of cultivation of edible crocodiles is shown in **Figure 4-5**, and a case of tilapia aquaculture is shown in **Figure 4-6**.

【Reference】

Neely, K. (2007): Geothermal resources in Idaho -A consumer's guide.
https://www.idahogeology.org/.../Geothermal/Geothermal_book.pdf

【Photo provided: Boyd, T.】

Figure 4-5 Aquaculture of Edible Crocodiles Using Geothermal Heat in Idaho

Figure 4-6 Aquaculture of Tilapia near Klamath Falls, Oregon

Source: Geothermal Resources Council Homepage
http://geothermalresourcescouncil.blogspot.com/2017/09/usa-oregon-geothermal.html

(2) Examples of agricultural drying

Figure 4-7 shows examples of direct utilization of geothermal energy. Onions and garlic are dried utilizing geothermal energy in Nevada. 4.5 - 6.8 tons of onions per hour are dried with hot water at 99°C, reducing moisture from 85% to 5%.

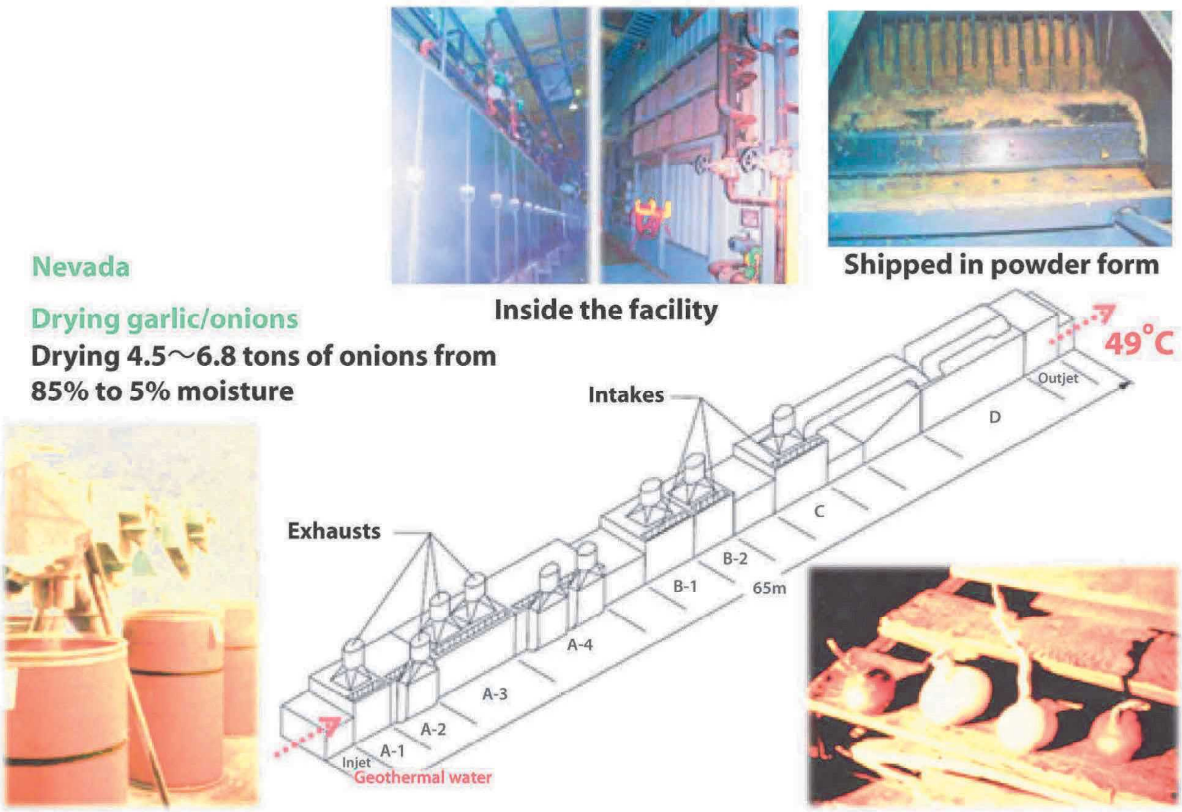


Figure 4-7 Example of Heat Utilization in the United States (Crop Drying)
【Kasumi Yasukawa (2018) International ONSEN summit materials】

(3) Examples of other uses

Although quantitatively small, there are some interesting cases of industrial utilization of geothermal in the United States, such as heating for heap leaching in which metal is eluted from ore and heating for catalytic reaction to produce sulfur from hydrogen sulfide (Bakane, 2013).

【Reference】

Bakane, P. (2013): Uses and advantages of geothermal resources in mining. GHC BULLETIN, 31 (4), 30-33.
https://oregontechsfstatic.azureedge.net/sitefinity-production/docs/default-source/geoheat-center-documents/quarterly-bulletin/vol-31/art7.pdf?sfvrsn=6d18d60_4

4.2.3 Geothermal power generation

Regarding the capacity of geothermal power generation facilities as of 2017, the USA is the world's No. 1 (3,719 MW, see **Table 2-3**). Major geothermal electric power plants are located in California, Nevada, Utah, and Hawaii with recent installation in Alaska, Idaho, New Mexico and Oregon. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The lowest temperature installed plant is at Chena Hot Springs in Alaska, where binary cycle plants use 74°C geothermal fluids to run three units for a total of 730 kW (gross). The location of major geothermal power plants in the US geothermal resources is shown in **Figure 4-8**.

Figure 4-8 Major Geothermal Power Plants Distributed in the Western United States

Source: Japan Agency for Natural Resources and Energy Homepage: Home> About Policy>Fuel> Geothermal Resource Policy/Geothermal Power Generation> Geothermal Page>Geothermal Power Generation Mechanism> Geothermal Power Plant Introduction> World Geothermal Power Plant
http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/mechanism/plant/foreign/

As an example of a geothermal power plant, the power plant in the Geysers area is shown in **Figure 4-9.** Located near the San Andreas fault, it is the world's largest dry steam geothermal field with an area of about 80 square kilometers. Geothermal energy comes from plutonic rocks related to the activities of the Clear Lake Volcanics.

Source: Japan Agency for Natural Resources and Energy Homepage: Home> About Policy>Fuel> Geothermal Resource Policy/Geothermal Power Generation> Geothermal Page>Geothermal Power Generation Mechanism> Geothermal Power Plant Introduction> World Geothermal Power Plant
http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/mechanism/plant/foreign/

Figure 4-9 Example of Geothermal Power Plants in the Geysers Area (Calpine Unit)

4.3 Indonesia

Geothermal resources in the country are associated with volcanoes in Sumatra, Java, Bali, and the islands in the eastern part of Indonesia.

4.3.1 Heat utilization

Geothermal resources have been used directly as hot springs and pools for hundreds of years in Indonesia. Prior to the 20th century, geothermal fluid (geothermal) was used only for bathing, washing, and cooking, but the use of geothermal fluids in recent years is very diverse. For example, the Indonesian Technology Evaluation and Application Agency (BPPT: Badan Pengkajian dan Penerapan Teknologi) is conducting research on utilizing geothermal energy in the agricultural field, especially on the use of sterilization of the growth medium used for mushroom cultivation.

Geothermal uses in agriculture are increasing. Examples of this usage are copra drying at Lahendong, Mataloko, Wai Ratai Lampung; cultivation of mushrooms at Pengalengan; drying and low-temperature sterilization of tea at Pengalengan; and direct use of geothermal energy for growing large catfish at Lampung.
In Lampung County, traditional freshwater large-catfish farming is being carried out by mixing natural geothermal water (outflow water) and fresh river water. This mixture of geothermal fluid and freshwater increases fish growth rates.

Figure 4-10 shows an example of mushroom cultivation using the bactericidal action of geothermal carried out in Camomoan, Indonesia.

Source: Surya Darma, Tisnaldi and Rony Gunawan (2015): Country Update: Geothermal Energy Use and Development in Indonesia, Proceedings World Geothermal Congress 2015

Figure 4-10 Example of Mushroom Cultivation Using the Bactericidal Geothermal Action (Kamojang, Indonesia)

Source: Surya Darma, Tisnaldi and Rony Gunawan (2015): Country Update: Geothermal Energy Use and Development in Indonesia, Proceedings World Geothermal Congress 2015

4.3.2 Geothermal power generation

The installed electrical capacity as of 2017 is 1,860 MW, ranked as world No 3 (**Table 2-3**). Indonesian geothermal resources are estimated at 30,000 MW. Operation of the first geothermal power plant began in 1984. Since then, geothermal power plants have been constructed in Gunung Salak (377 MW), Darajat (260 MW), and Kamojang (200 MW). The government has set a goal of 7,100 MW for geothermal power plant construction by 2025, and development is expected to continue to accelerate in the future. Japanese companies are participating in geothermal development in Indonesia, and Kyushu Electric Power Co., Ltd., and ITOCHU Corporation are taking part in the construction of power plants with a total output of 330 MW in Sarulla, North Sumatra (Kaieda, 2018).

The installed capacity of power generation facilities in each region of Indonesia is shown in **Table 4-2.**

【Reference】

Hideshi Kaieda (2018): Trend of geothermal power generation overseas, geology and survey, No. 2018 2, pp. 41- 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf